



PixelRadDamage 3D Sensor Digitizer

Status Update

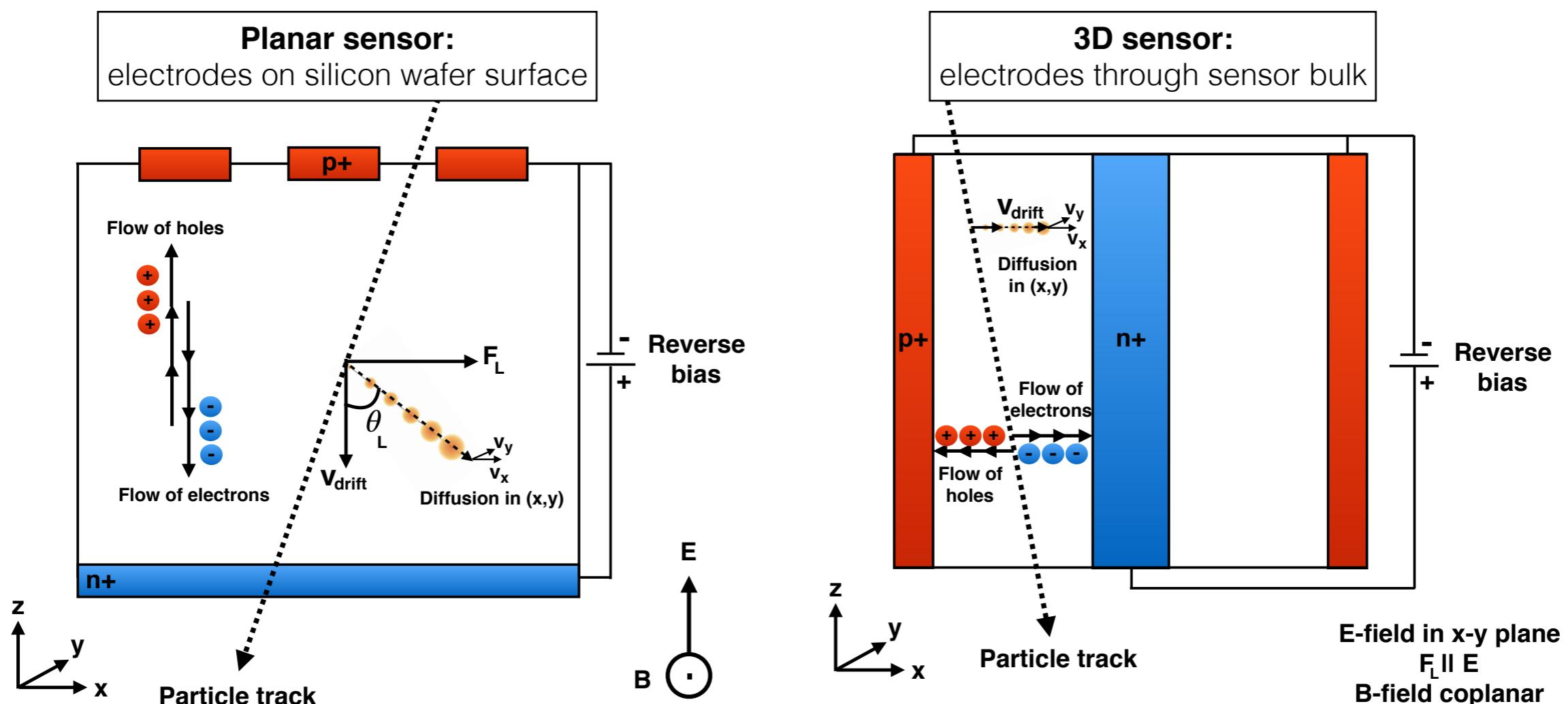
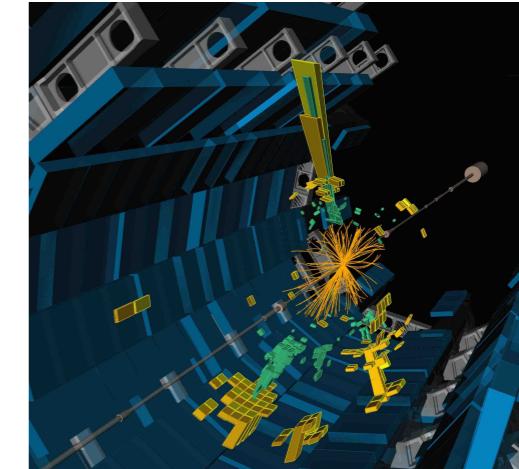
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November 18 2016

Reminder

Adding pixel radiation damage effects to the ATLAS simulation software

- ◆ Affects charge collection → charge trapping cause signal loss
- ◆ Added in digitization step (energy deposit from hits converted to ToT)
- ◆ Modeled for planar sensors (Ben, Rebecca et. al)
- ◆ To be extended for 3D sensors: different E-field orientation

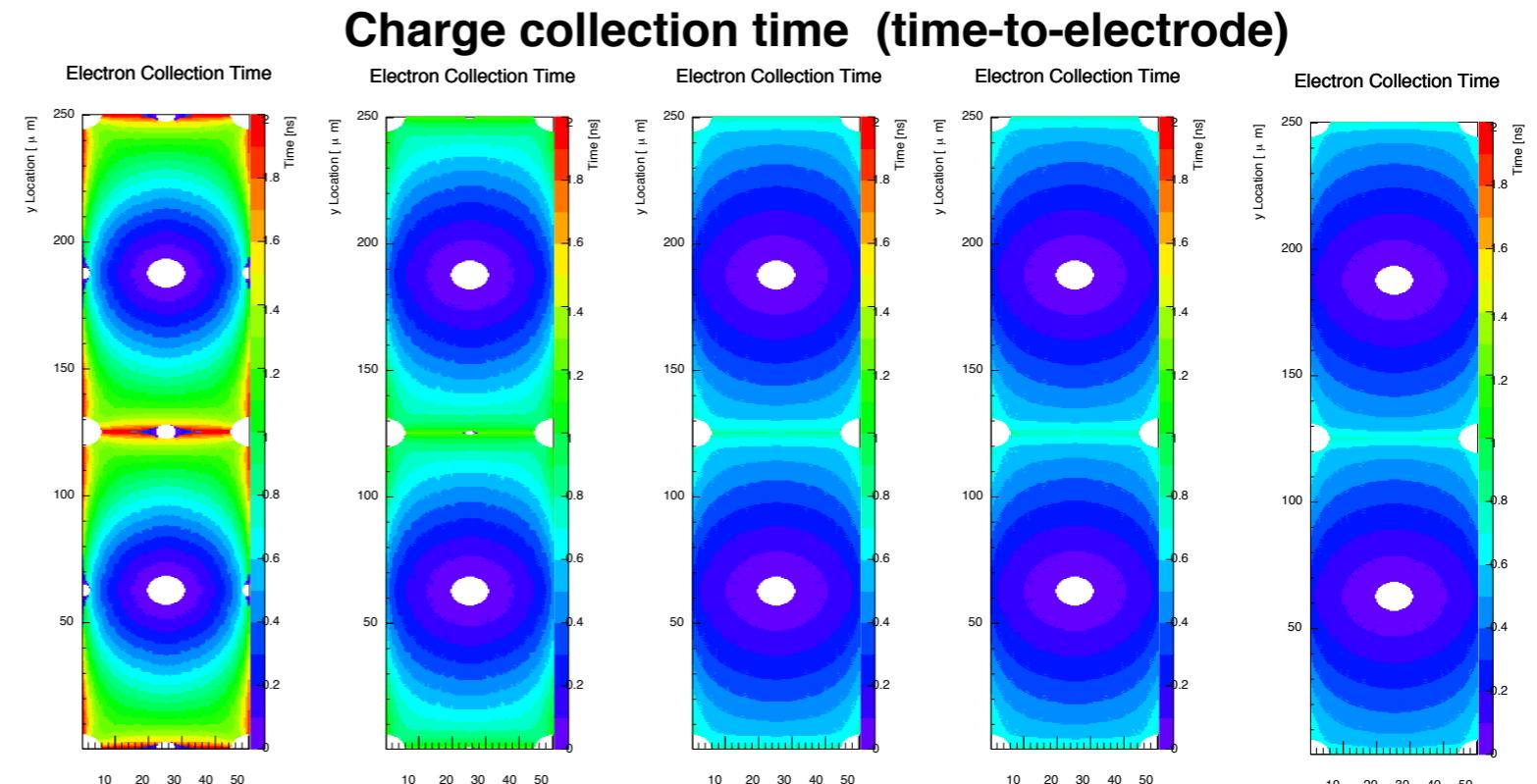
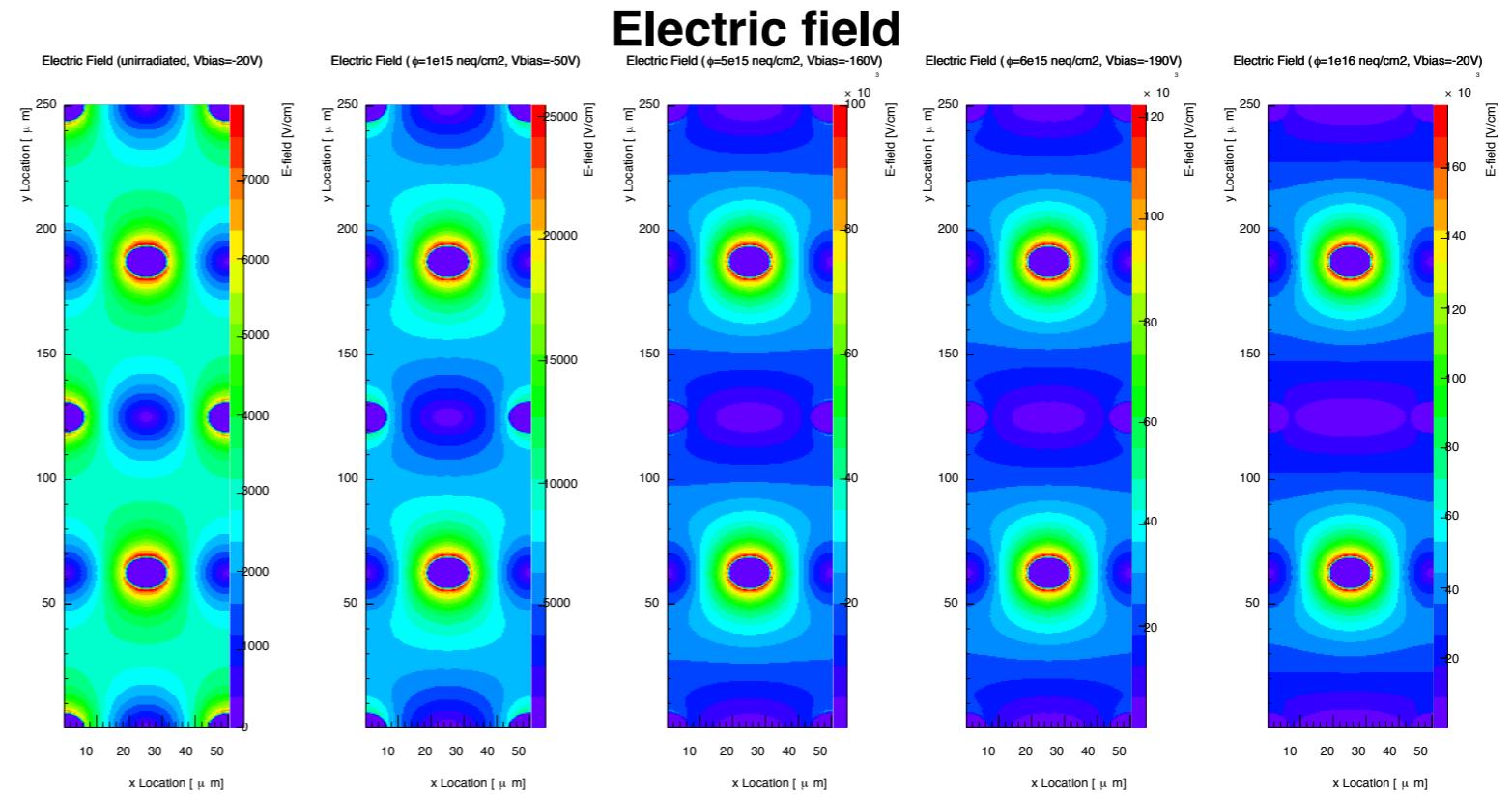


TCAD Maps: E-field & Collection Time

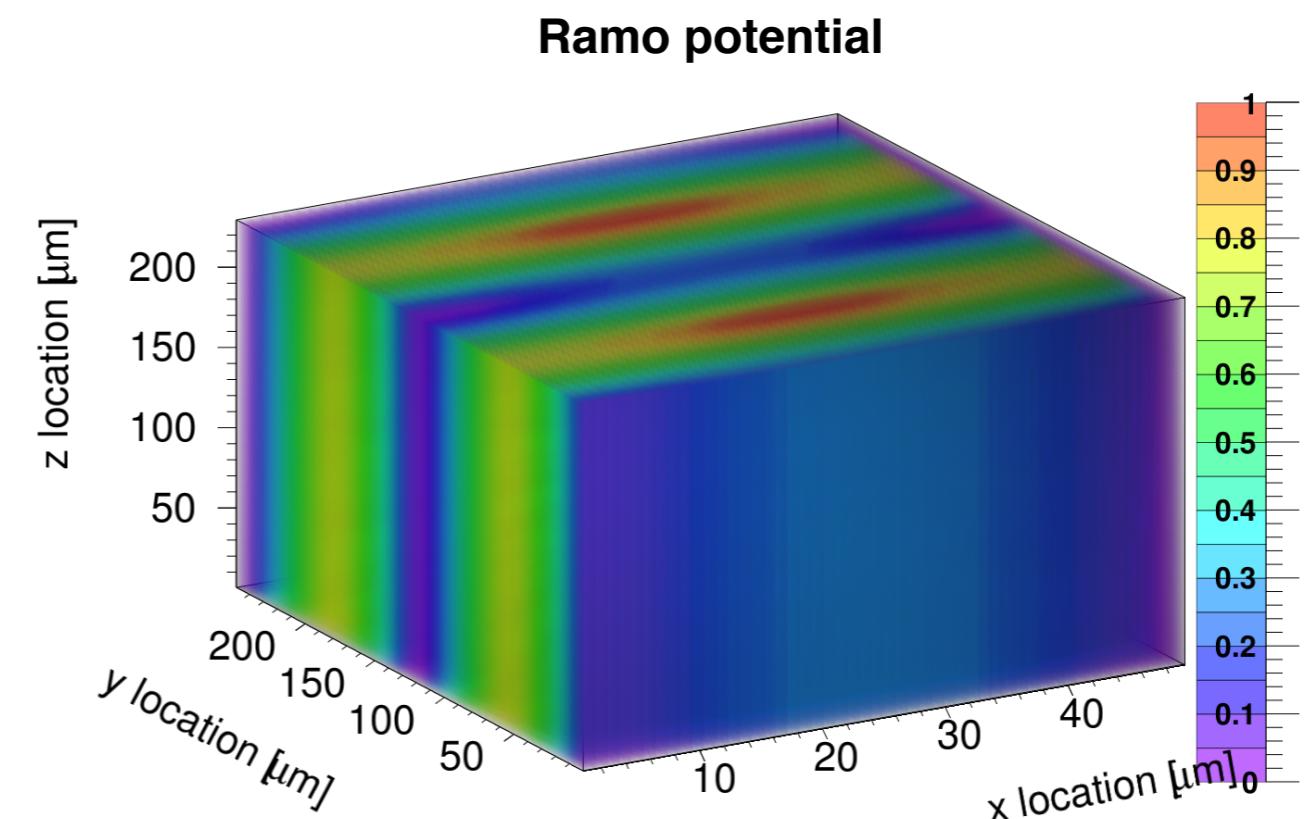
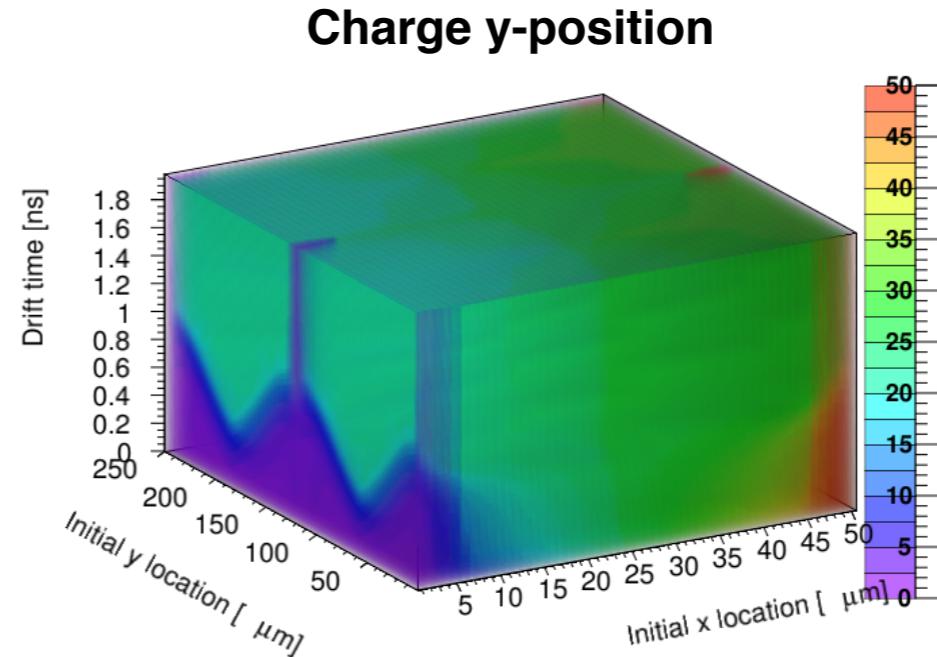
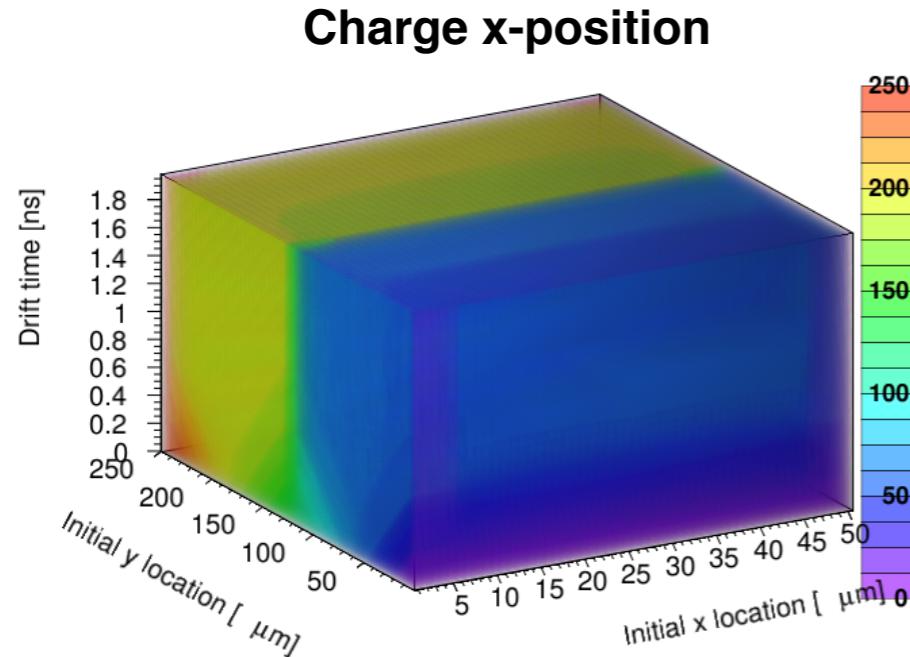
Data from TCAD simulations used to generate lookup tables (ROOT histograms)

| Fluence [neq/cm ²] | V _{bias} [V] |
|--------------------------------|-----------------------|
| unirradiated | -20 |
| 1×10^{15} | -50 |
| 5×10^{15} | -160 |
| 6×10^{15} | -190 |
| 1×10^{16} | -260 |

Required bias for full depletion increases with fluence



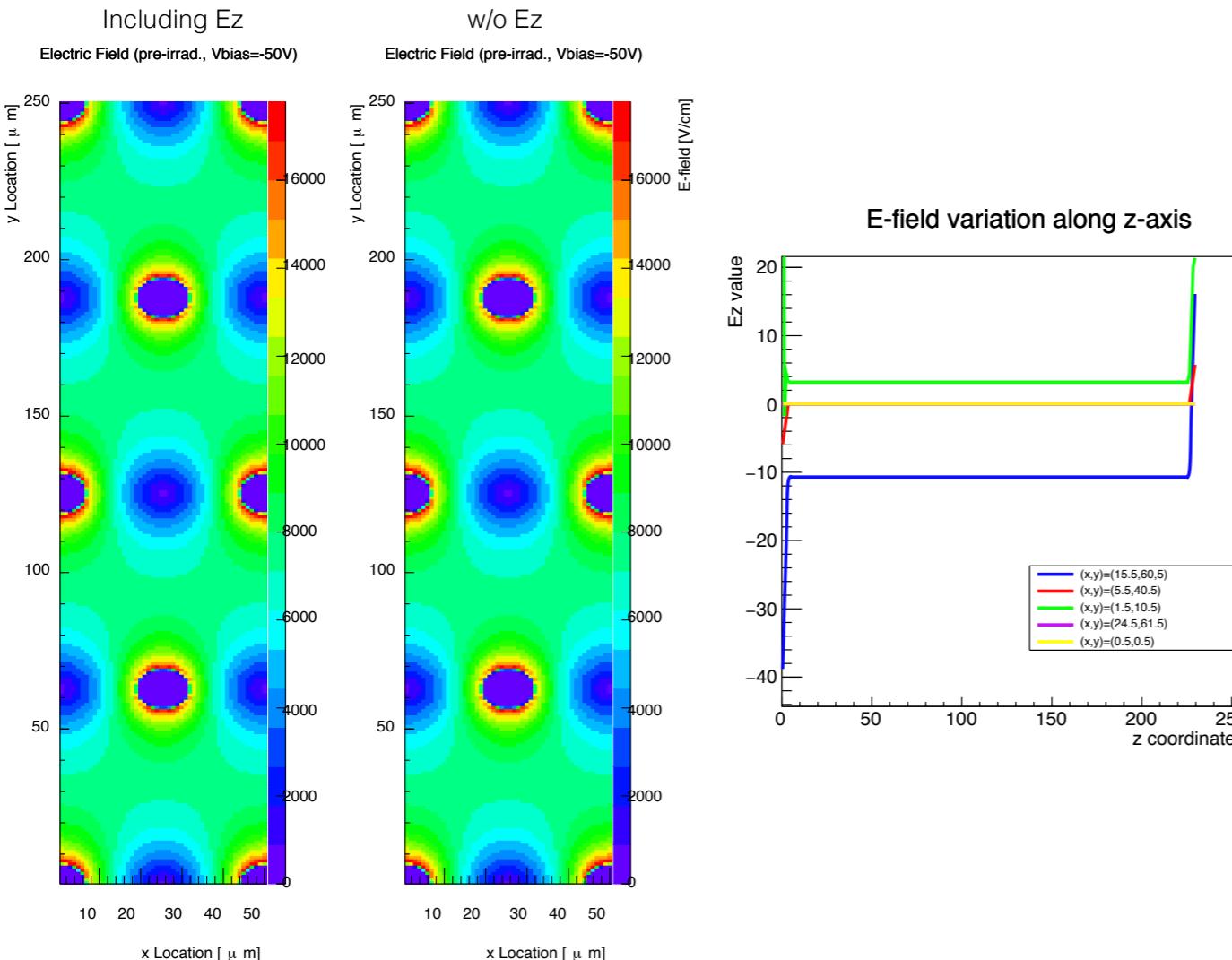
TCAD Maps: Induced Charge



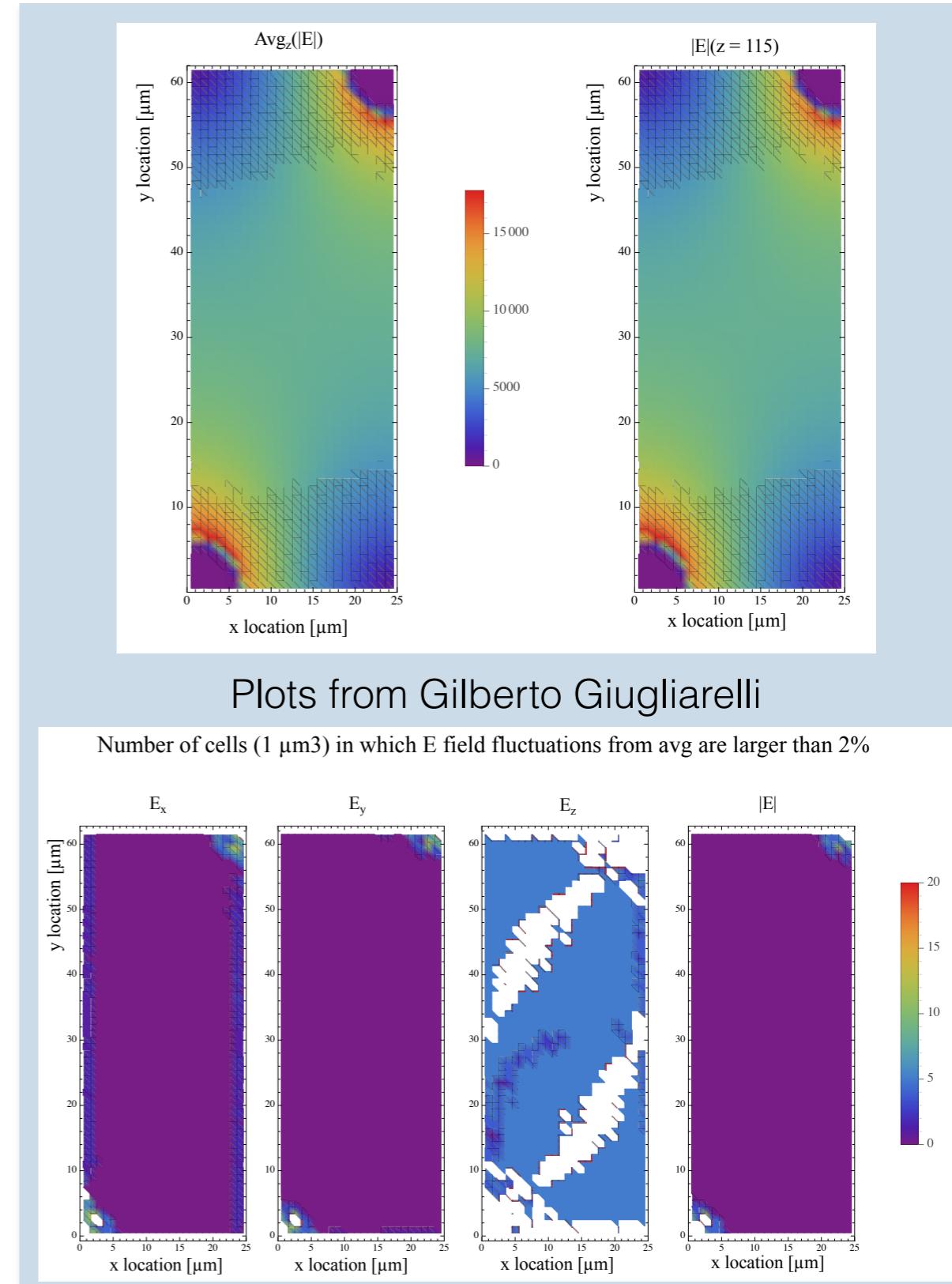
Movement of charge cause signal formation, thus trapped charges contribute to the signal and this is modeled by *Ramo potential* ϕ :

$$E_{\text{Ramo}} = E_{\text{hit}}(\phi_{\text{final}} - \phi_{\text{initial}})$$

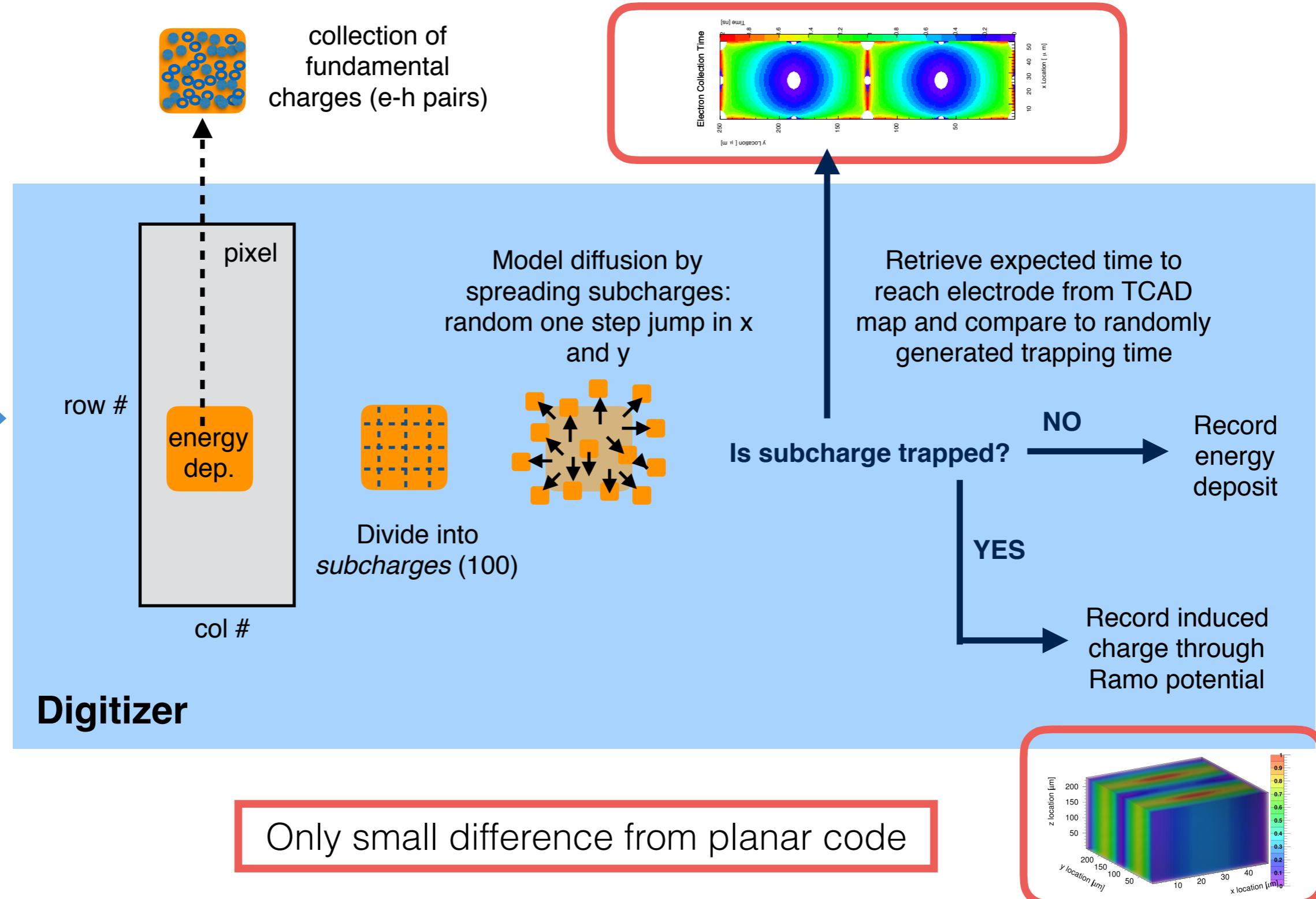
TCAD Maps: Z-Dependence



**Small dependence on z:
use x-y plane in middle of sensor**

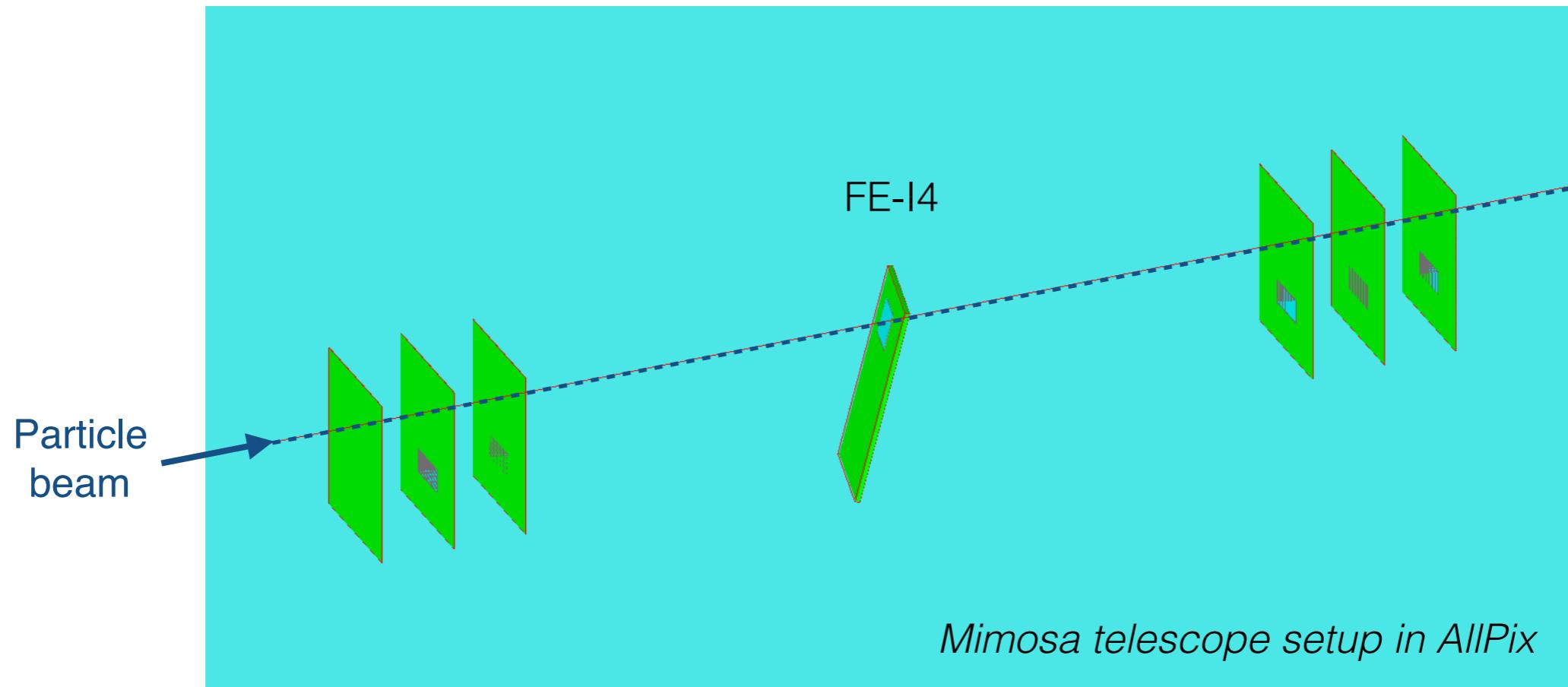


3D Algorithm



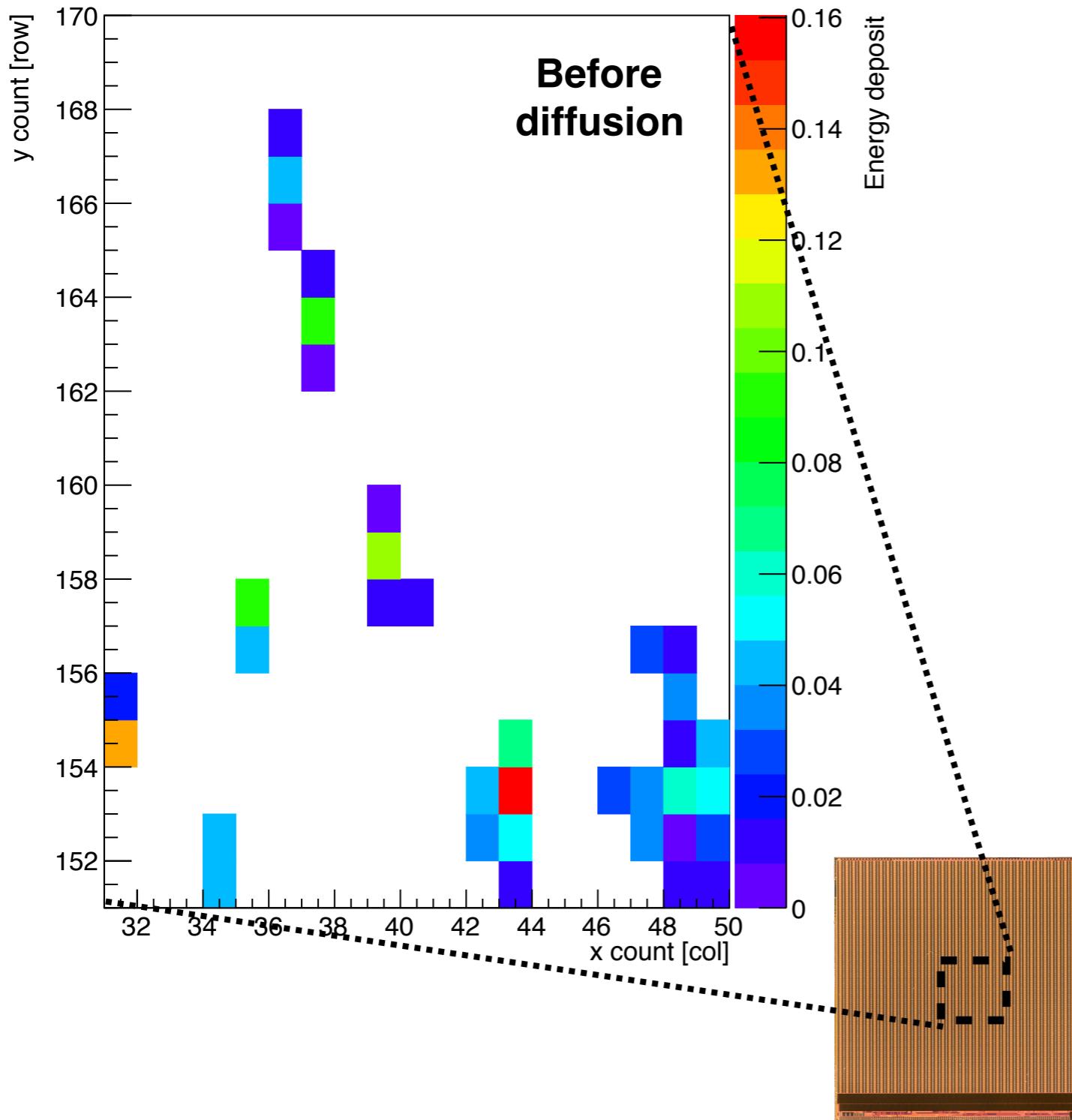
Verification

- ♦ Minimal working example of 3D digitizer set up in **Allpix** (development framework)
 - ♦ First intuitive look of behavior
 - ♦ Recorded energy deposit with/without rad. damage effects

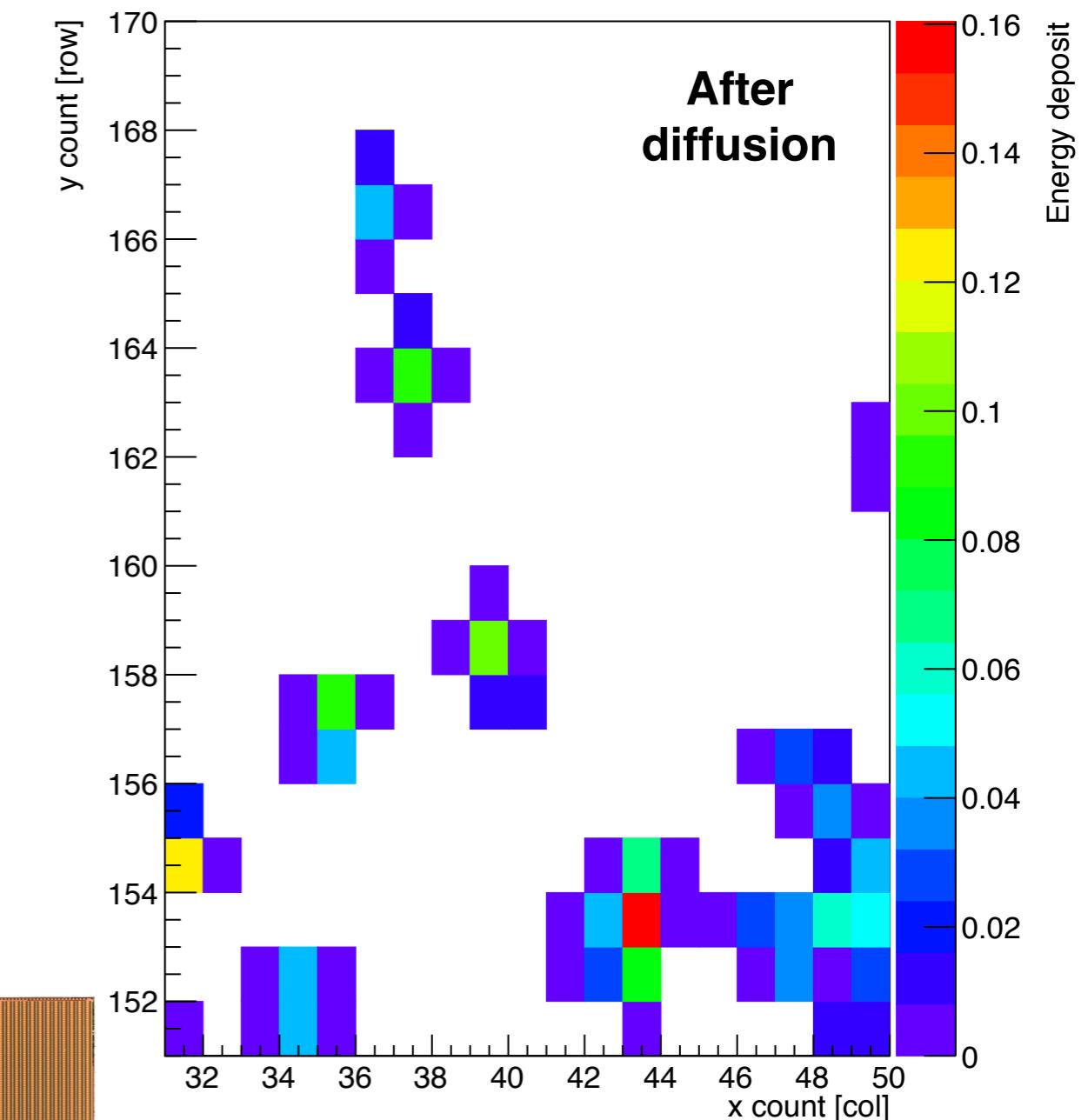


Diffusion

FEI4 energy deposit pre-diffusion (300 runs, unirradiated, Vbias=-20V)



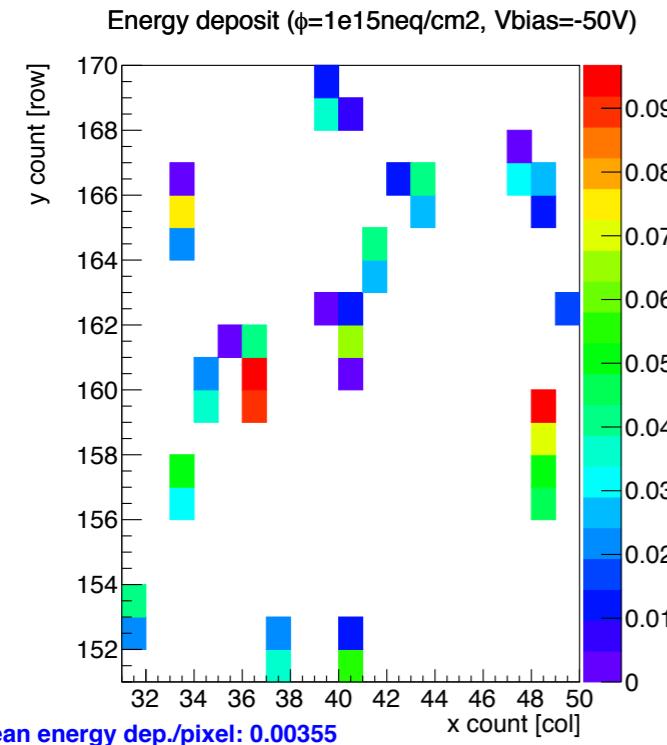
FEI4 energy deposit post-diffusion (300 runs, unirradiated, Vbias=-20V)



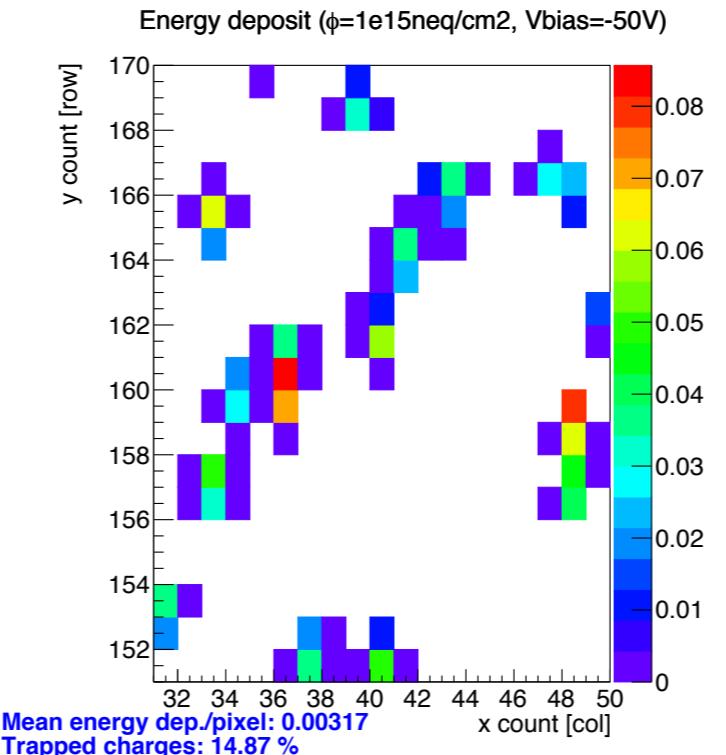
Greater charge sharing in x because pixel dimensions (y pitch > x pitch)

RadDamage Effects (300 runs)

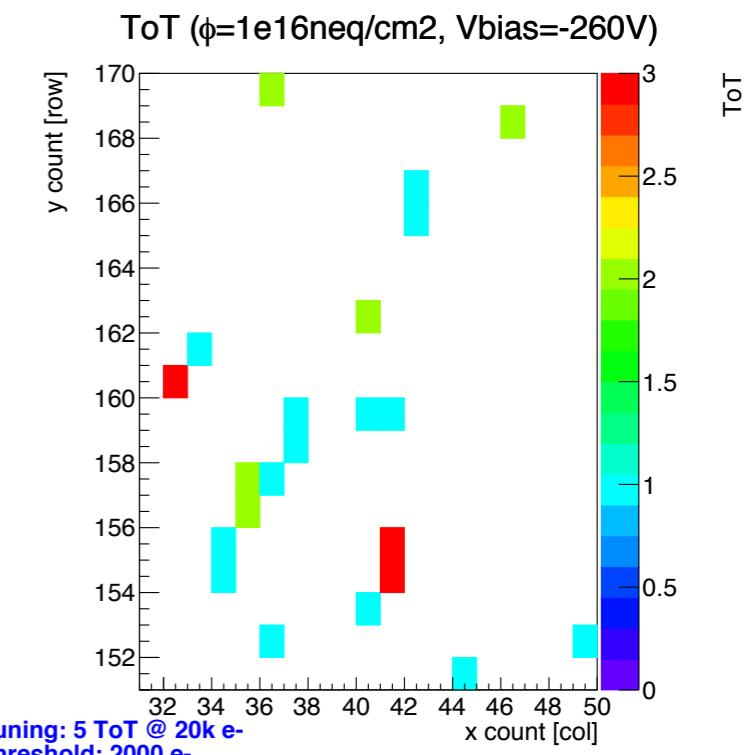
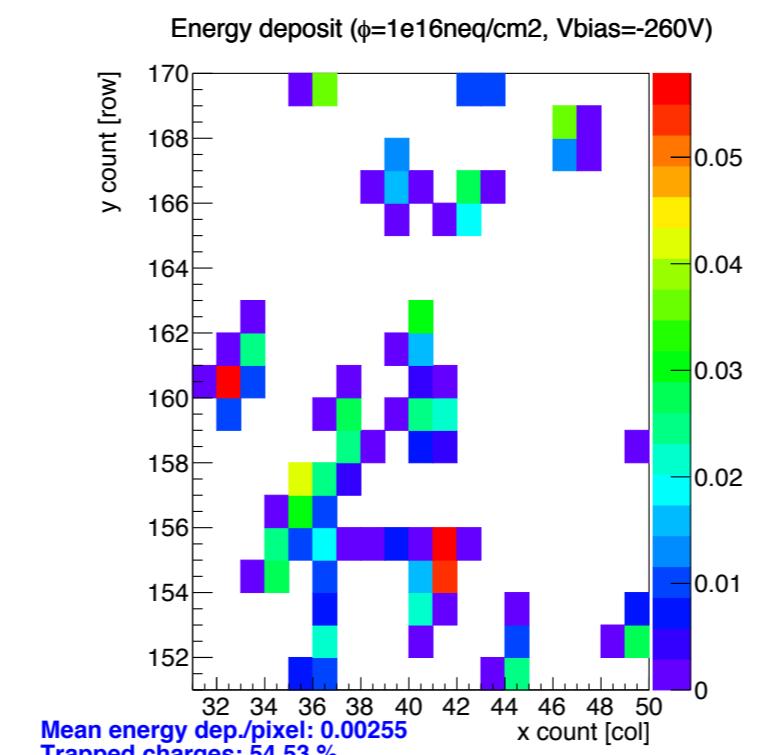
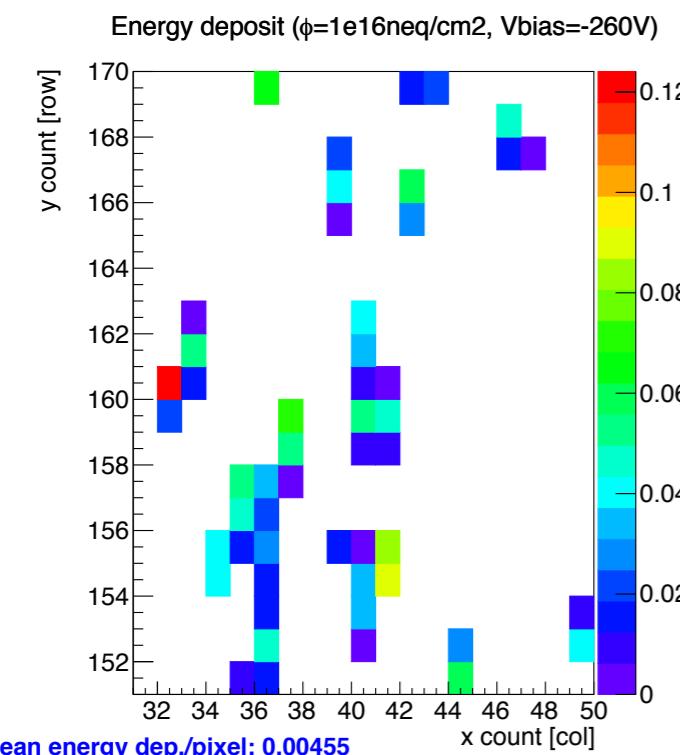
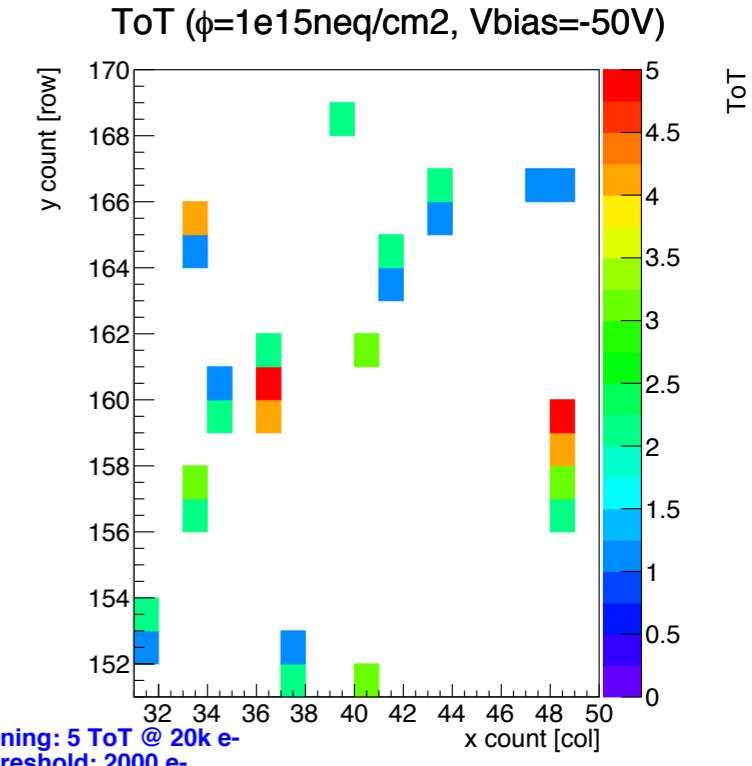
Energy deposit w/o RadDamage



RadDamage effects added

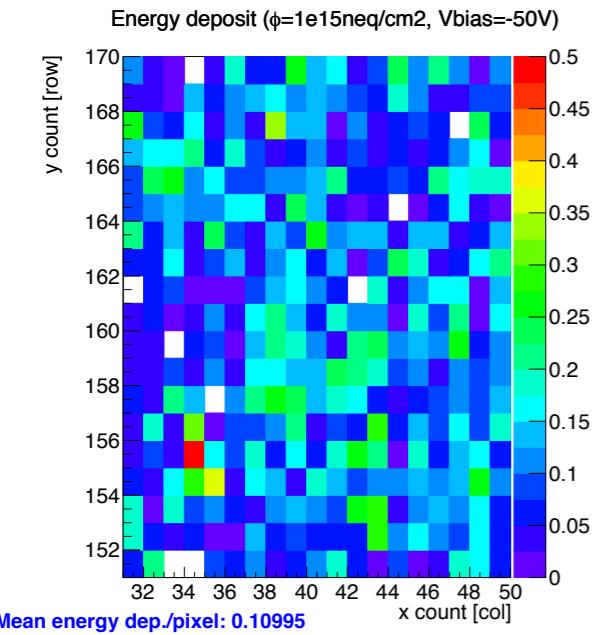


After digitization: ToT

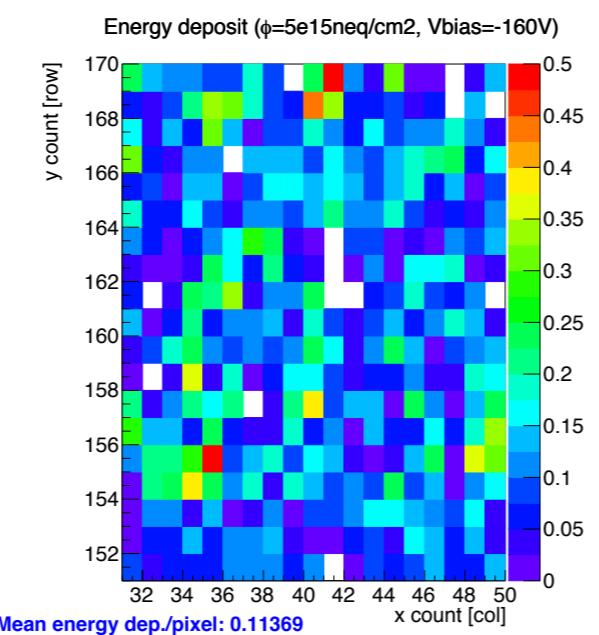


RadDamage effects (10,000 runs)

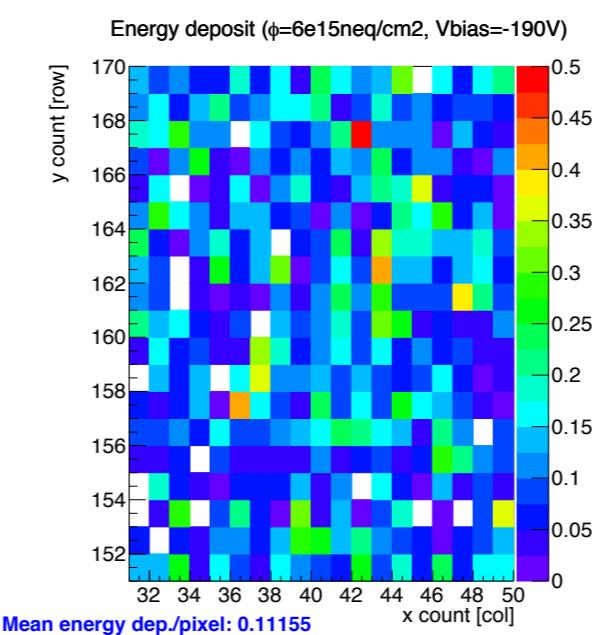
$\Phi=10^{15}$ neq/cm²



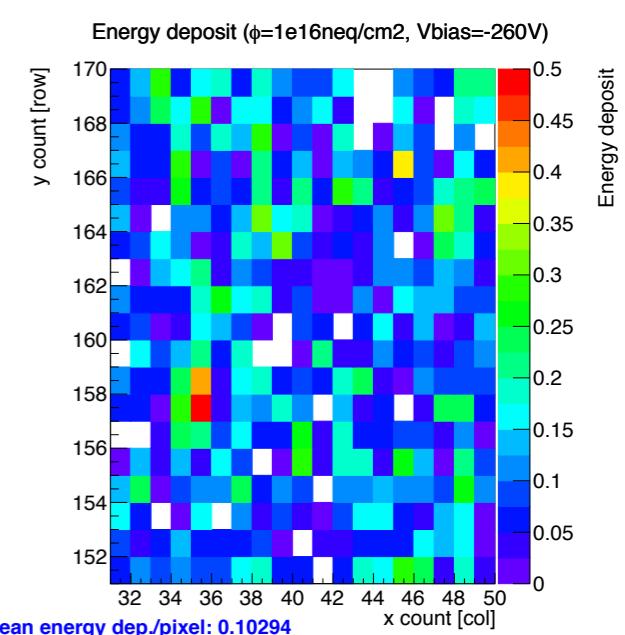
$\Phi=5\times 10^{15}$ neq/cm²



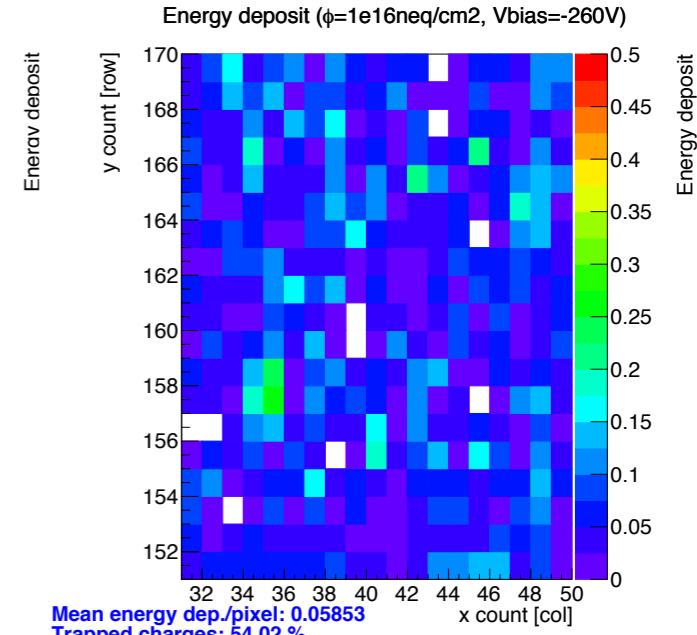
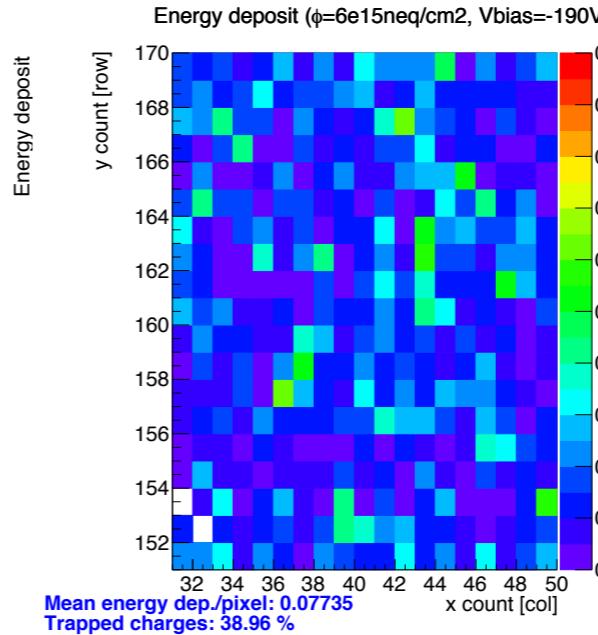
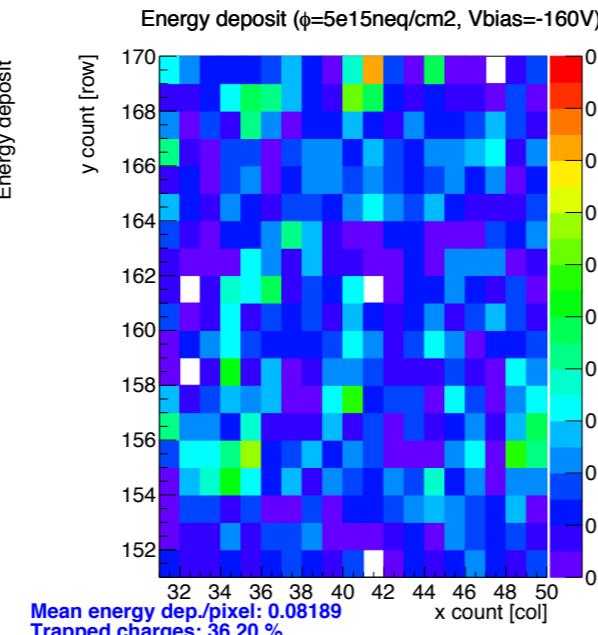
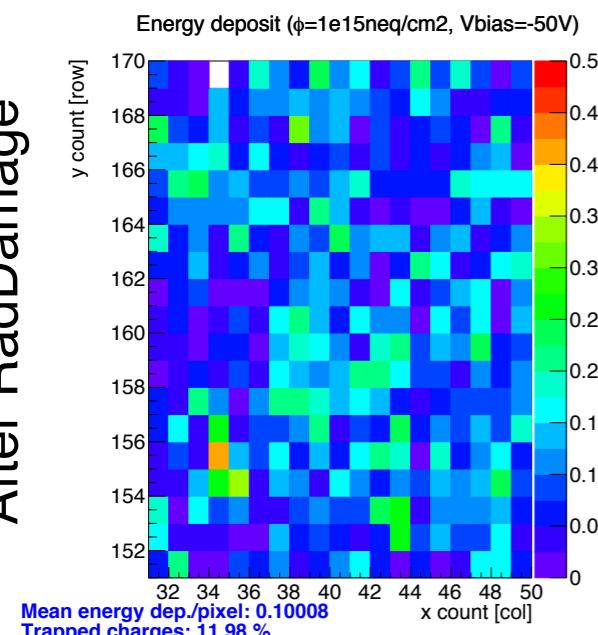
$\Phi=6\times 10^{15}$ neq/cm²



$\Phi=10^{16}$ neq/cm²

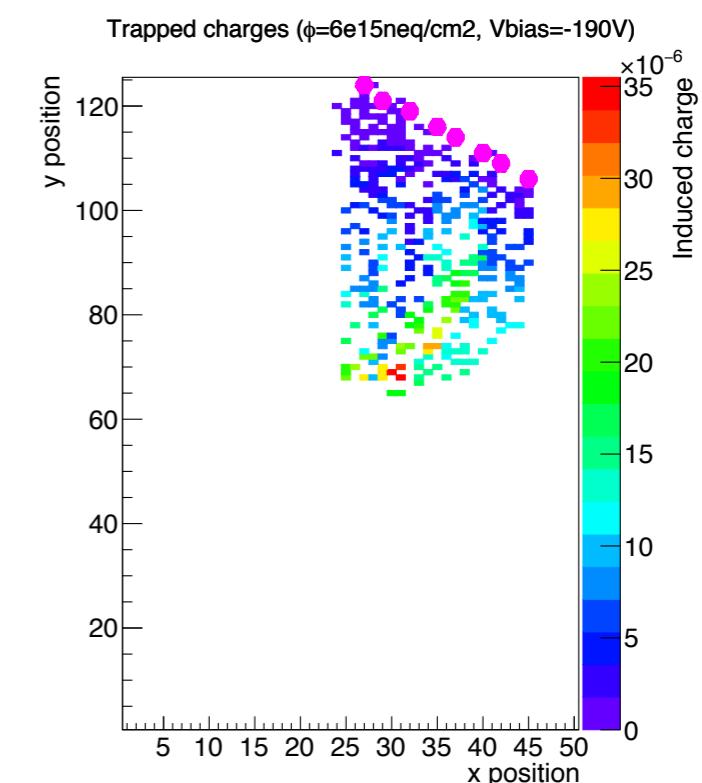
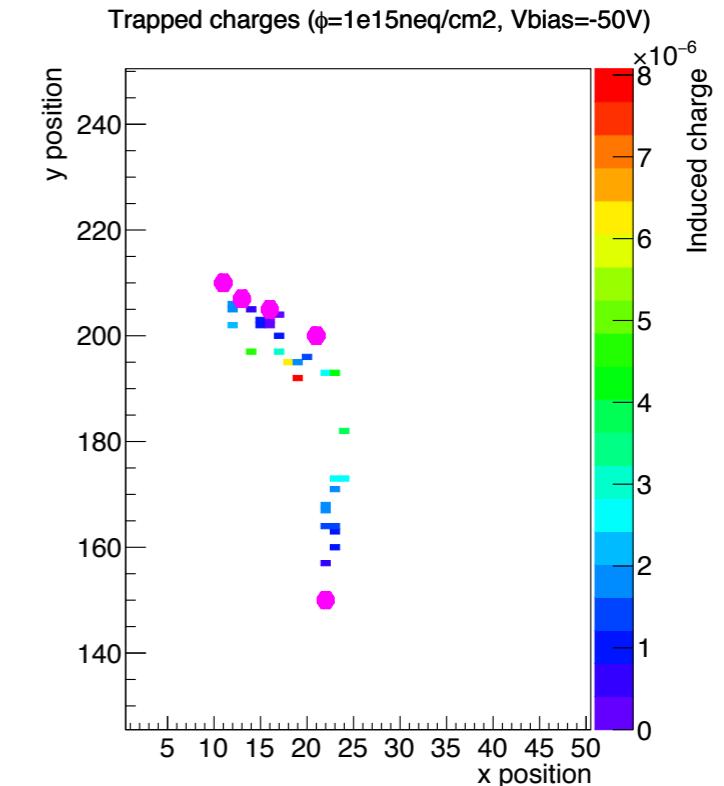
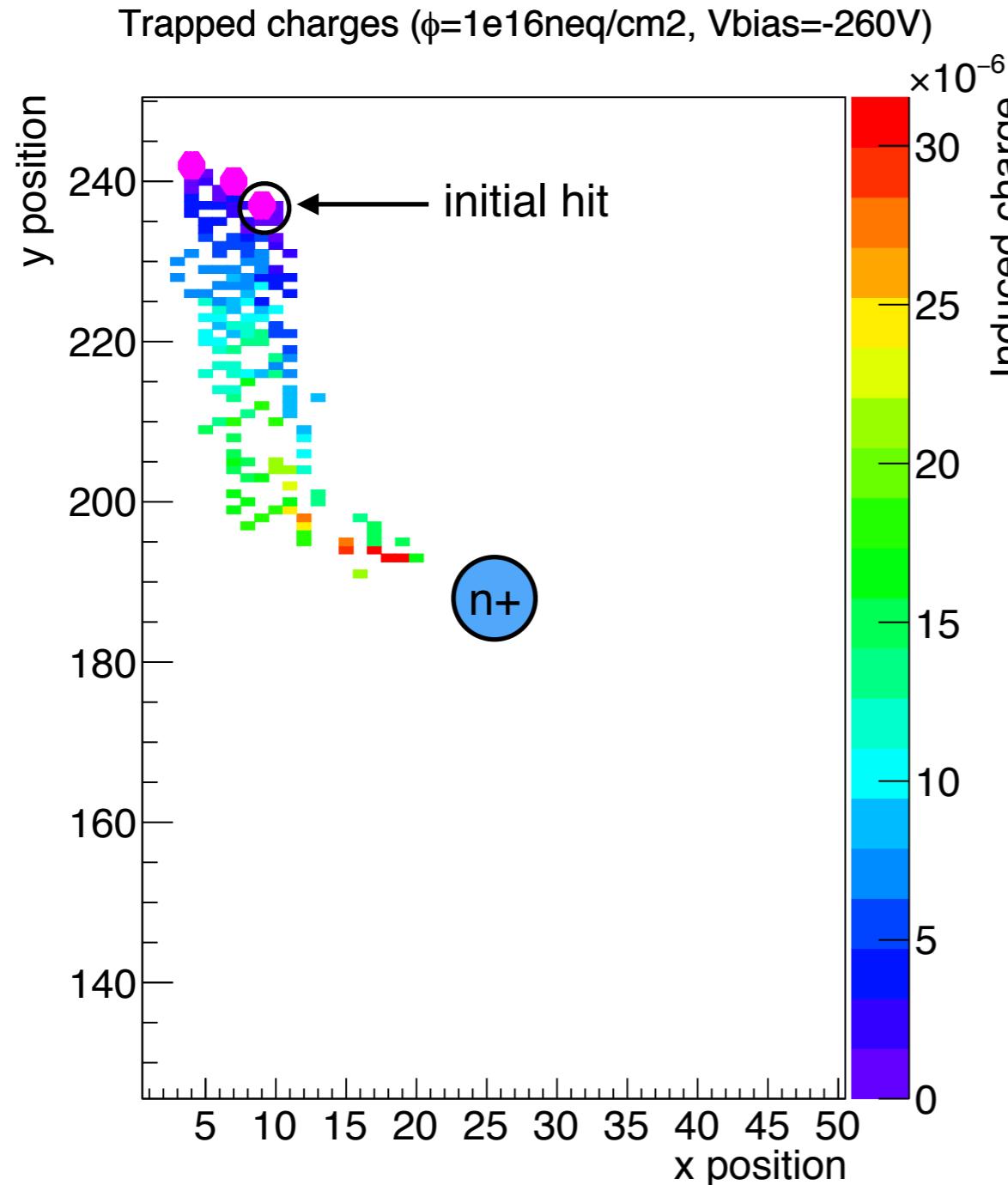


After RadDamage



Induced signal from trapped charges

- ◆ “Tracking” charges in one hit pixel as processed by 3D code
- ◆ Visualize how single charges are propagated through sensor



To-do

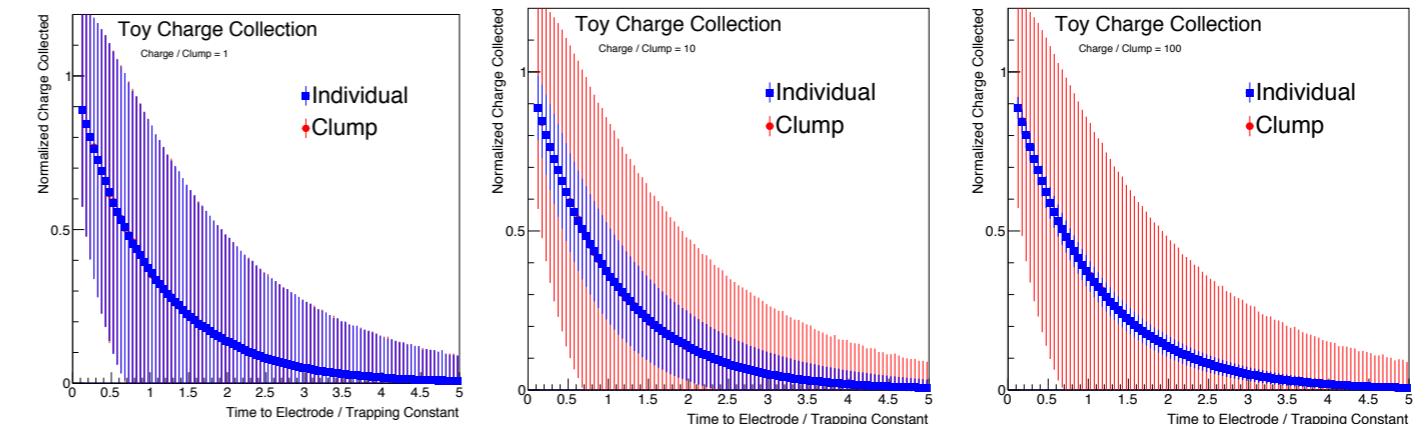
- ◆ Negative energy deposit when computing induced charge through Ramo potential..?
- ◆ Induced charge in neighboring pixels
- ◆ Extend code for holes
- ◆ Charge chunking effect

Fluctuation Correction

Slide from Ben

The problem: our ‘subcharges’ are not fundamental.

On average, the charge collected is correct, but the fluctuations are wrong (too big)



Two solutions:

Increase the number of subcharges (not feasible)
 Apply a correction to ‘unsmear’ the charge distribution